Twentieth Century Storminess:
Developing a Coherent Understanding of Long-term Trends and Decadal Variability

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Abstract
Severe Extra-Tropical Cyclones are the major meteorological hazard to Europe. In total, the 10 most severe wind storms produced an insured damage of about US$ 34.2bn. Since the 1960s a steadily increase in North-Atlantic/European Storminess was observed until the mid-90s of the last century. This high level of storm activity and its related losses were strongly discussed in the light of anthropogenic climate change. Recent scientific research, investigating the 20th Century Reanalysis (1871-2008), reveals that North-Atlantic/European Storminess might be underlying a long-term positive trend with unprecedented high values in recent decades. This is partly not in common with local station observations (e.g. in the Netherlands) and questions concerning the coherence of different storminess measures are not answered yet. On the other side, reasons of multi-decadal variability of storminess are not fully identified and a broader understanding of storm variability is missing. Both problems might be linked. This project aims thus to develop a comprehensive understanding of storm variability for the last ca. 140 years. Consequently, ***research area 1*** will further develop published research findings to coherent physical mechanisms leading to extreme storminess on synoptic scales as well as on multi-decadal scales. Thus, the link between surface based trend signals and steering mechanisms in the mid-troposphere will be investigated. ***Research Area 2*** focuses on the role of large-scale precursor situations to wind storms and analyses in how far known teleconnection pattern (NAO) are consistent with the storminess signal identified. ***Research Area 3*** will specifically investigate in how far a maximum of storminess at the beginning of the last century compares to the latest peak in activity. Potential differences in the physical steering mechanisms as well as in the large-scale conditions will be addressed. The findings should be discussed in the context of detection and attribution of anthropogenic climate change signals.

Introduction
Severe Extra-Tropical Cyclones are the major meteorological hazard to Europe. In total the 10 most severe wind storms produced an insured damage of about US$ 34.2bn. The uninsured losses are by far larger and are estimated to about US$ 56bn (MunichRe, 2010; original values). This numbers give an impression of the relevance of reliable information on variability of wind storms over Europe on time scales from days (synoptic forecast) to centuries (e.g. anthropogenic climate change). Since the 1960s a steadily increase in North Atlantic / European Storminess was observed until the mid-90s of the last century (e.g. Leckebusch et al., 2008). Although in the last decade this positive trend was not supported anymore, the high level of storm activity and its related loss of insured and uninsured values were strongly discussed in the light of anthropogenic climate change. The origin and physical mechanisms for this multi-decadal trend are unclear and it is actually related to natural climate variability as e.g. the phase shifts of the **N**orth **A**tlantic **O**scillation or multi-decadal variations of the **A**tlantic **M**ultidecadal **O**scillation (AMO) (Nissen et al., 2011), although anthropogenic influences cannot be ruled out (Ulbrich et al., 2009). This is mainly due to the relatively short time span of reliable observations suitable for storminess detection. Thus, it could not be ruled out that previously in the last century not similar or even higher storminess were reality.

State-of-the-art scientific knowledge
Recent scientific research, investigating a state-of-the-art 4 dimensional atmospheric data set (20th Century Reanalysis, 1871-2008; Compo et al., 2011), reveals that North Atlantic European Storminess might be underlying a long-term positive trend with unprecedented high values in the last part of the investigation period (Donat et al., 2011). From mean sea-level pressure data (Wang et al., 2011) and station data (The

Netherlands, Smits et al., 2005), this trend is not identified, or even a reverse one observed. Vautard et al. (2010) discuss in this context increased surface roughness in the vicinity of meteorological station, but a clear and comprehensive explanation of this inconsistency is not obvious. An analysis of the physical mechanisms leading to the development of severe ETCs in century long reanalysis data is missing and would contribute to the general understanding of storm variability and its consistent representation in reanalysis data. One major question is here, in how far mid- to upper-troposphere steering conditions are consistent with storminess trends based on surface information. On the other side, large scale variability modes in reanalyses, like the NAO (strongly related to the occurrence of wind storms, Pinto et al. 2009), might be captured in different ways and thus feedback the surface-near wind conditions.

Aims

This projects aims to develop a comprehensive understanding of storm variability for the last ca. 140 years. By means of different available (20CR, NCEP/NCAR) and soon upcoming (ECMWF) reanalysis for the last century, newly developed datasets are available for such a study, which could not be fulfilled before due to the lack of adequate data. Three main topics will be addressed: generation processes of severe ETCs in reanalysis data, large scale steering factors for variability of storminess (frequency and intensity), and detection of anthropogenic fingerprints in the observed storminess trend of the last thirty years of the last century.

Consequently, ***research area 1*** will further develop published research findings in the light of coherent physical mechanisms leading to extreme storminess on synoptic scales as well as on multi-decadal scales. This will mean the coherence of the surface based trend signal with steering mechanisms in the mid-troposphere will investigated. ***Research Area 2*** will focus on the role of large-scale precursor situations to wind storms and analyse in how far known teleconnection pattern (NAO) are consistent with the storminess signal identified. ***Research Area 3*** will specifically investigate in how far a maximum of storminess at the beginning of the last century compares to the latest peak in activity. Potential differences in the physical steering mechanisms as well as in the large-scale conditions are to be addressed. The findings will be discussed in the context of detection and attribution of anthropogenic climate change signals.

Methods

The student will apply state-of-the-art diagnostic tools to identify severe ETCs and will learn how to investigate dynamical forcing factors for the generation of wind storms on the synoptic scale. Further on, the intended work will need new development of further analysis methods to relate large scale variability modes on decadal to multi-decadal time scales to steering factors acting on seasons or intra-seasonal scales. Besides dynamical based diagnosis, the student will learn to use multivariate statistical methods and tools to investigate spatial-temporal variability and its link to specific meteorological extreme events. Thus, recent developments to analyse partly inhomogeneous data sets in the context of extreme value statistics will be used and prepared for meteorological applications.

Selected References.

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